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NETS 2021

Nuclear and Emerging Technologies for Space

Yale Chang

Considerations for Implementing Presidential Memorandum-20 Guidelines for Nuclear Safety Launch Authorization for Future Civil Space Missions

APL JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Nuclear Technology Journal Paper

Nuclear and Emerging Technologies for Space
Knoxville, TN, April 6 – April 9, 2020, available online at https://nets2020.ornl.gov

NETS 2020

CONSIDERATIONS FOR IMPLEMENTING PRESIDENTIAL MEMORANDUM-20 GUIDELINES FOR NUCLEAR SAFETY LAUNCH AUTHORIZATION FOR FUTURE CIVIL SPACE MISSIONS

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National Security Presidential Memorandum-20 (NSPM-20) (Launch of Spacecraft Containing Space Nuclear Systems) [1] dated 20 August 2019 provides updated guidelines for launch authorization for three categories of proposed launches of spacecraft with space nuclear systems: Federal Government civil space including NASA, Federal Government defense and intelligence, and commercial. These space nuclear systems provide power, heat, and/or propulsion to the spacecraft.

NSPM-20 states: "For United States launches of space nuclear systems, the Federal Government must ensure a rigorous, risk informed safety analysis and launch authorization process" [1], primarily by examining the probabilities of potential launch and reentry accidents and their consequences. At the same time, for previous NASA missions, the launch approval process "has taken an average of six years and costs over $40 million" [2]. In an effort to streamline the process, and improve cost and schedule, NSPM-20 provides specific guidelines including the following: (1) "to the extent possible, safety analyses and reviews should incorporate previous mission and review experience" [e.g., Environmental Impact Statements (EISs), Records of Decision (RODs), Safety Analysis Reports (SARs), and Safety Evaluation Reports (SERs)], (2) "demonstrate that the mission is within the safety basis envelope established in the system-specific SAR, in which case it is not necessary to repeat the analysis supporting the system-specific SAR," and (3) "authorization for launches of spacecraft containing space nuclear systems shall follow a three-tiered process based on the characteristics of the system, the level of potential hazard, and national security considerations" (i.e., use risk-adjusted metrics for required level of effort and launch authorization authority).

A future example interplanetary mission (EIM) that plans to use a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) is covered by NSPM-20, and is used here as a proxy to illustrate potential considerations for implementing NSPM-20 guidelines. Assume that this EIM plans to use one or two Earth Gravity Assist (EGA) maneuvers in its mission trajectory and that it will use launch vehicle (LV) stages with solid propellant. Its LV will definitely have a Flight termination system (FTS).

This paper investigates each of these three NSPM-20 guidelines for three accident categories associated with the EIM: (1) EGA (aka Earth flyby or Earth swing-by) reentry, (2) solid propellant fires, and (3) FTS functions and probabilities. This paper also identifies the components needed to implement each guideline in a rigorous fashion, then assesses whether the necessary components (e.g., analyses, reports, tests, reviews, risk communications, previous launch approvals) currently exist or would need to be produced or modified.

Although these NSPM-20 guidelines could be logical and appropriate approaches for evaluating the risk associated with a system-of-systems (i.e., launch of nuclear systems) that has reached steady-state, the current state of affairs for the EIM is likely still in the "start-up transient" phase. For example, past EISs and SARs for each successive mission were constantly updated with new test data, new technology, new knowledge, and new understanding, such that previous risk results could change [3]. Additionally, past SARs proactively considered review comments and findings from past SERs. Therefore, one potential future side effect of the proposed cost improvement approach is the stagnation of technological progress in nuclear safety analyses.

Because there are no cases of launch authorization of commercial launches of nuclear systems, and no previous unclassified detailed guidelines for launch authorization of defense or intelligence launches of nuclear systems, this paper refers to relevant NASA missions.

I. THREE ACCIDENT CATEGORIES

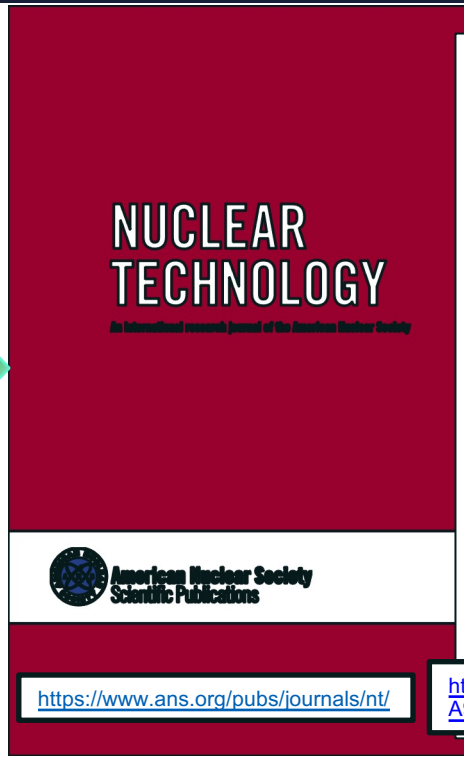
The three specific NSPM-20 guidelines for the three EIM accident categories are discussed next.

I.A. Earth Gravity Assist Reentry Accident

The last NASA radioisotope power systems (RPS) missions with EGA maneuvers were Galileo (1989 launch) and Cassini (1997 launch). Galileo successfully flew a Venus-Earth-Earth-Gravity-Assist (VEEGA) mission trajectory, and Cassini successfully flew a Venus-Venus-Earth-Jupiter-Gravity-Assist (VVEJGA) mission trajectory.

I.A.1. Previous Mission Analysis and Review Experience

https://nets2020.ornl.gov/wp-content/uploads/2020/09/TRACK-3-Full-submission.pdf



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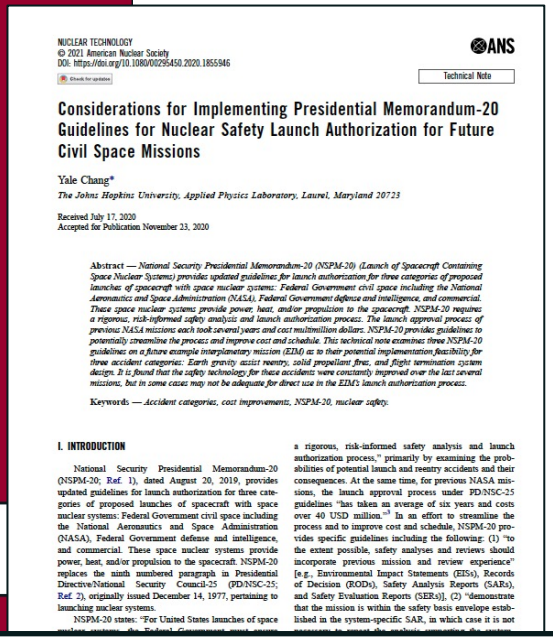

NUCLEAR TECHNOLOGY
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DOI: https://doi.org/10.1080/00295450.2020.1855946

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Technical Note

Considerations for Implementing Presidential Memorandum-20 Guidelines for Nuclear Safety Launch Authorization for Future Civil Space Missions

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Received July 17, 2020
Accepted for Publication November 23, 2020

Abstract — *National Security Presidential Memorandum-20 (NSPM-20) (Launch of Spacecraft Containing Space Nuclear Systems) provides updated guidelines for launch authorization for three categories of proposed launches of spacecraft with space nuclear systems: Federal Government civil space including the National Aeronautics and Space Administration (NASA), Federal Government defense and intelligence, and commercial. These space nuclear systems provide power, heat, and/or propulsion to the spacecraft. NSPM-20 requires a rigorous, risk-informed safety analysis and launch authorization process. The launch approval process of previous NASA missions each took several years and cost multimillion dollars. NSPM-20 provides guidelines to potentially streamline the process and improve cost and schedule. This technical note examines three NSPM-20 guidelines on a future example interplanetary mission (EIM) as to their potential implementation feasibility for three accident categories: Earth gravity assist reentry, solid propellant fires, and flight termination system design. It is found that the safety technology for these accidents were constantly improved over the last several missions, but in some cases may not be adequate for direct use in the EIM's launch authorization process.*

Keywords — *Accident categories, cost improvements, NSPM-20, nuclear safety.*

I. INTRODUCTION

National Security Presidential Memorandum-20 (NSPM-20; Ref. 1), dated August 20, 2019, provides updated guidelines for launch authorization for three categories of proposed launches of spacecraft with space nuclear systems: Federal Government civil space including the National Aeronautics and Space Administration (NASA), Federal Government defense and intelligence, and commercial. These space nuclear systems provide power, heat, and/or propulsion to the spacecraft. NSPM-20 replaces the ninth numbered paragraph in Presidential Directive/National Security Council-25 (PD/NSC-25; Ref. 2), originally issued December 14, 1977, pertaining to launching nuclear systems.

NSPM-20 states: "For United States launches of space

a rigorous, risk-informed safety analysis and launch authorization process," primarily by examining the probabilities of potential launch and reentry accidents and their consequences. At the same time, for previous NASA missions, the launch approval process under PD/NSC-25 guidelines "has taken an average of six years and costs over 40 USD million."[2] In an effort to streamline the process and to improve cost and schedule, NSPM-20 provides specific guidelines including the following: (1) "to the extent possible, safety analyses and reviews should incorporate previous mission and review experience" [e.g., Environmental Impact Statements (EISs), Records of Decision (RODs), Safety Analysis Reports (SARs), and Safety Evaluation Reports (SERs)], (2) "demonstrate that the mission is within the safety basis envelope established in the system-specific SAR, in which case it is not

https://www.tandfonline.com/eprint/WPBSFBZHDI2ICQT6A9CM/full?target=10.1080/00295450.2020.1855946

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  - APL Payload Rep, New Horizons launch

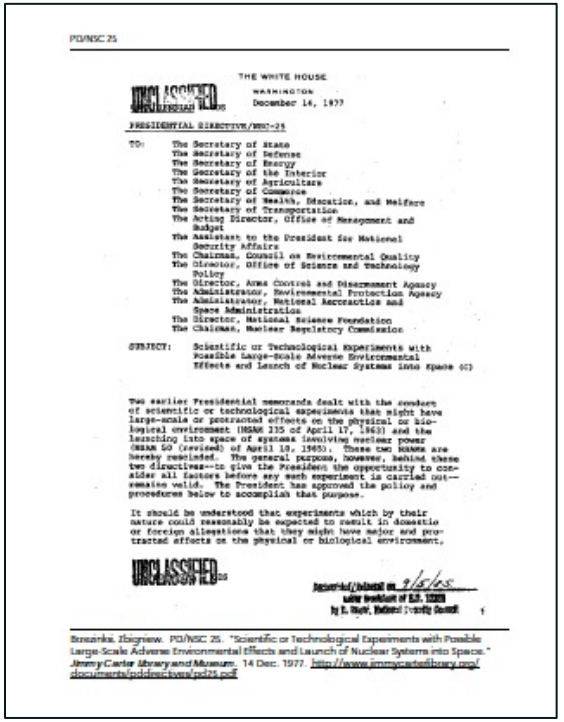
APL Payload Representative, New Horizons launch, Radiological Control Center (RADCC) at the NASA Kennedy Space Center, FL, January 2006

Launch of Space Nuclear Systems

- Any scientific or technological experiment either licensed or funded by Federal Agencies, which could reasonably be expected to result in major and protracted effects on the physical or biological environment, requires an environmental impact statement and Presidential launch approval.

  Presidential Directive / National Security Council Memorandum 25 (**PD/NSC 25**), December 14, 1977

- Covered NASA missions **Galileo, Cassini, New Horizons, Mars Science Laboratory, and Mars 2020** with **Radioisotope Thermoelectric Generators (RTGs)**
- Complex process viewed by some as costly and lengthy, with few specific requirements or guidelines



PD/NSC 25

THE WHITE HOUSE

UNCLASSIFIED

WASHINGTON

December 14, 1977

PRESIDENTIAL DIRECTIVE/NSC-25

TO: The Secretary of State
The Secretary of Defense
The Secretary of Energy
The Secretary of the Interior
The Secretary of Agriculture
The Secretary of Commerce
The Secretary of Health, Education, and Welfare
The Secretary of Transportation
The Acting Director, Office of Management and Budget
The Assistant to the President for National Security Affairs
The Chairman, Council on Environmental Quality
The Director, Office of Science and Technology Policy
The Director, Arms Control and Disarmament Agency
The Administrator, Environmental Protection Agency
The Administrator, National Aeronautics and Space Administration
The Director, National Science Foundation
The Chairman, Nuclear Regulatory Commission

SUBJECT: Scientific or Technological Experiments with Possible Large-Scale Adverse Environmental Effects and Launch of Nuclear Systems into Space (U)

Two earlier Presidential memoranda dealt with the conduct of scientific or technological experiments that might have large-scale or protracted effects on the physical or biological environment (NSAM 235 of April 17, 1963) and the launching into space of systems involving nuclear power (NSAM 50 (revised) of April 18, 1965). These two memos are hereby rescinded. The general purpose, however, behind these two directives--to give the President the opportunity to consider all factors before any such experiment is carried out--remains valid. The President has approved the policy and procedures below to accomplish that purpose.

It should be understood that experiments which by their nature could reasonably be expected to result in domestic or foreign allegations that they might have major and protracted effects on the physical or biological environment,

UNCLASSIFIED

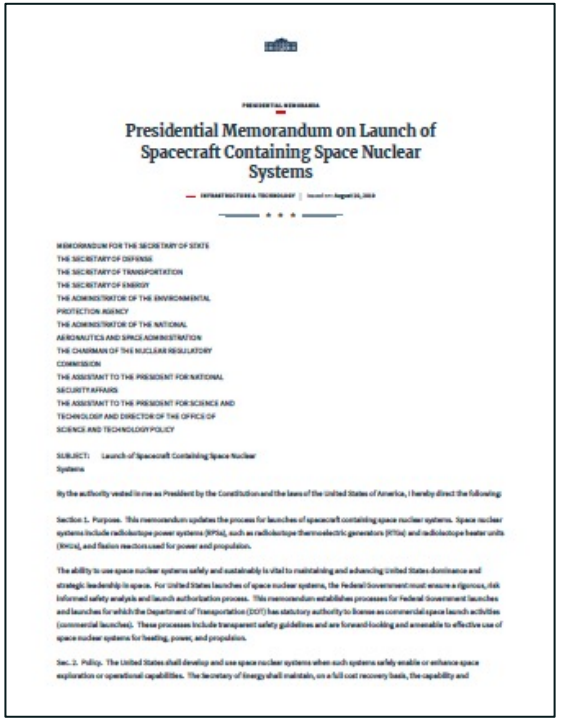
Brzezinski, Zbigniew. PD/NSC 25. "Scientific or Technological Experiments with Possible Large-Scale Adverse Environmental Effects and Launch of Nuclear Systems into Space." Jimmy Carter Library and Museum. 14 Dec. 1977. http://www.jimmycarterlibrary.org/documents/pddirectives/pd25.pdf

National Security Presidential Memorandum-20 (NSPM-20) (1/3)

- **NSPM-20** (Launch of Spacecraft Containing Space Nuclear Systems [that provide power, heat, and/or propulsion]), August 20, 2019, provides updated guidelines for launch authorization of:
  - Commercial,
  - Federal Government defense and intelligence,
  - **Federal Government civil space including NASA**

- NSPM-20 states "For United States launches of space nuclear systems, the Federal Government must ensure a rigorous, risk informed safety analysis and launch authorization process" primarily by examining the probabilities of potential launch and reentry accidents and their consequences.

- At the same time, for previous NASA missions, the launch approval process "has taken an average of six years and costs over $40 million." [Howieson, Behrens, Kowal, NETS 2019]



Presidential Memorandum on Launch of Spacecraft Containing Space Nuclear Systems

MEMORANDUM FOR THE SECRETARY OF STATE
THE SECRETARY OF DEFENSE
THE SECRETARY OF TRANSPORTATION
THE SECRETARY OF ENERGY
THE ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY
THE ADMINISTRATOR OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
THE CHAIRMAN OF THE NUCLEAR REGULATORY COMMISSION
THE ASSISTANT TO THE PRESIDENT FOR NATIONAL SECURITY AFFAIRS
THE ASSISTANT TO THE PRESIDENT FOR SCIENCE AND TECHNOLOGY AND DIRECTOR OF THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY

SUBJECT: Launch of Spacecraft Containing Space Nuclear Systems

By the authority vested in me as President by the Constitution and the laws of the United States of America, I hereby direct the following:

Section 1. Purpose. This memorandum updates the process for launches of spacecraft containing space nuclear systems. Space nuclear systems include radioisotope power systems (RPSs), such as radioisotope thermoelectric generators (RTGs) and radioisotope heater units (RHUs), and fission reactors used for power and propulsion.

The ability to use space nuclear systems safely and sustainably is vital to maintaining and advancing United States dominance and strategic leadership in space. For United States launches of space nuclear systems, the Federal Government must ensure a rigorous, risk informed safety analysis and launch authorization process. This memorandum establishes processes for Federal Government launches and launches for which the Department of Transportation (DOT) has statutory authority to license as commercial space launch activities (commercial launches). These processes include transparent safety guidelines and are forward-looking and amenable to effective use of space nuclear systems for heating, power, and propulsion.

Sec. 2. Policy. The United States shall develop and use space nuclear systems when such systems safely enable or enhance space exploration or operational capabilities. The Secretary of Energy shall maintain, on a full cost recovery basis, the capability and

NSPM-20 (2/3)

- In an effort to streamline the process, and reduce cost and schedule, NSPM-20 provides specific **guidelines**:
  1. "To the extent possible, safety analyses and reviews should incorporate **previous mission [analysis] and review experience**" (e.g., Environmental Impact Statements (EISs), Records of Decision (RODs), Safety Analysis Reports (SARs), and Safety Evaluation Reports (SERs);
  2. "demonstrate that the mission is within the safety basis envelope established in the **system-specific SAR**, in which case it is not necessary to repeat the analysis supporting the system-specific SAR"; and
  3. "Authorization for launches of spacecraft containing space nuclear systems shall follow a **three-tiered process based upon** the characteristics of the system, the level of potential hazard, and national security considerations," i.e., use **risk-adjusted metrics** for required level of effort (LOE) and launch authorization authority.

NSPM-20 (3/3)

- A future **example interplanetary mission (EIM)** that plans to use a Multi-Mission Radioisotope Thermoelectric Generator (MMRTG) will be covered by NSPM-20. Assume that this EIM
  - I.A plans to use one or two **Earth Gravity Assist (EGA)** maneuvers in its mission trajectory,
  - I.B will use launch vehicle (LV) stages with **solid propellant,**
  - I.C its LV will definitely have a **flight termination system (FTS).**

  These are the EIM's three accident categories

Comparison of Cost & Schedule for NSPM-20 relative to PD/NSC-25 for EIM

The **Objectives** are to **Improve** Cost & Schedule via these **Guidelines**.

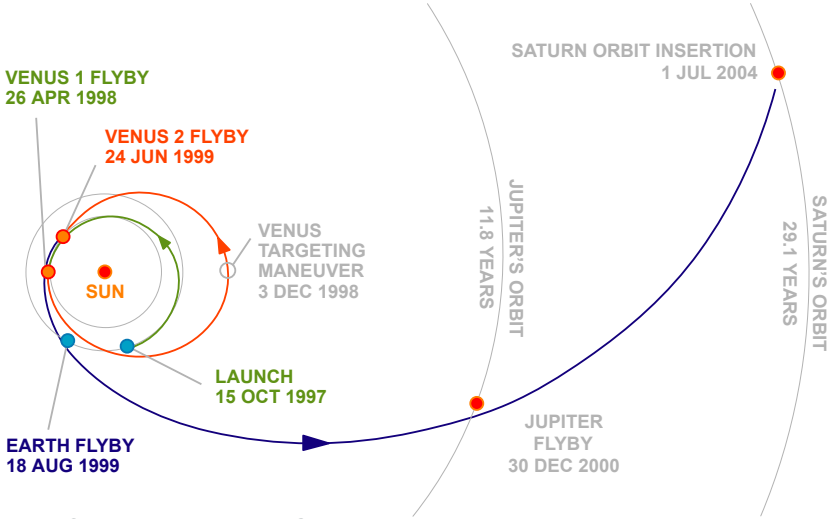
	NSPM-20 Guidelines		
Accident Category	**Previous analyses & reviews**	**System-specific SAR**	**Tier I, II, or III**
Earth Gravity Assist Reentry	**Improve**	**Improve**	**Improve**
Solid Propellant Fires	**Improve**	**Improve**	**Improve**
Flight Termination System	**Improve**	**Improve**	**Improve**

Comparison of Cost & Schedule for NSPM-20 relative to PD/NSC-25 for EIM

Realistically, Cost & Schedule will be **Similar** to past experiences.

	NSPM-20 Guidelines		
Accident Category	**Previous analyses & reviews**	**System-specific SAR**	**Tier I, II, or III**
Earth Gravity Assist Reentry	**INSRP disagreement w/FSAR; earlier technology (25-50 yr)**	**Environments exceed ground test capabilities**	**SER estimates may trigger Tier III**
Solid Propellant Fires	**Different EIS risks; different test results at SL and Hi Alt**	**Measured environments exceed MPs of Pu and Ir**	**MSL EIS exceeds Tier III thresholds**
Flight Termination System	**Risk estimates sensitive to assumptions and timing**	**Different FTSs for different LVs**	**FTS tuned for safety vs execution**

Earth Gravity Assist Reentry Accident



Cassini VVEJGA mission trajectory

Previous analyses & reviews

- Cassini's Interagency Nuclear Safety Review Panel (INSRP) found the Safety Analysis Report had a surface energy balance error, bias in heat transfer rates, underestimation of aerodynamic heating uncertainties, and unrealistic reentry orientation. Also GPHS module structural changes (Step 0 vs Step 2 designs).

System-specific SAR

- Predicted environments at 19.5 km/s (1000 g's, >7500º F, 400 MW/m^2) exceed ground-based test capabilities, such as arc jet tunnels

Tier I, II, or III launch authorization

- INSRP: "hypothetical 'collective cancer risk' of about 1500 latent cancer fatalities"
- Possibly Tier III (Presidential)

Solid Propellant Fire Accident

Mid-Atlantic Regional Spaceport Pad 0A is seen on Oct. 28, 2014 after Orbital Sciences' Antares rocket, with the robotic Cygnus spacecraft onboard, suffered a catastrophic anomaly moments after launch at NASA's Wallops Flight Facility in Virginia.
(Image: © NASA/Joel Kowsky)

- **Previous analyses & reviews**
  - **Two independent testing campaigns at Sea Level (more severe) and at High Altitude (6340 ft) (more benign)**
- **System-specific SAR**
  - **Measured SL fire environments (3000 K, 2 MW/m^2) exceed iridium clad and plutonia melting points**
- **Tier I, II, or III**
  - **Mars Science Laboratory EIS reports risks that exceed NSPM-20 Tier III thresholds (> 25 rem TED; > 1E-6)**

Flight Termination System

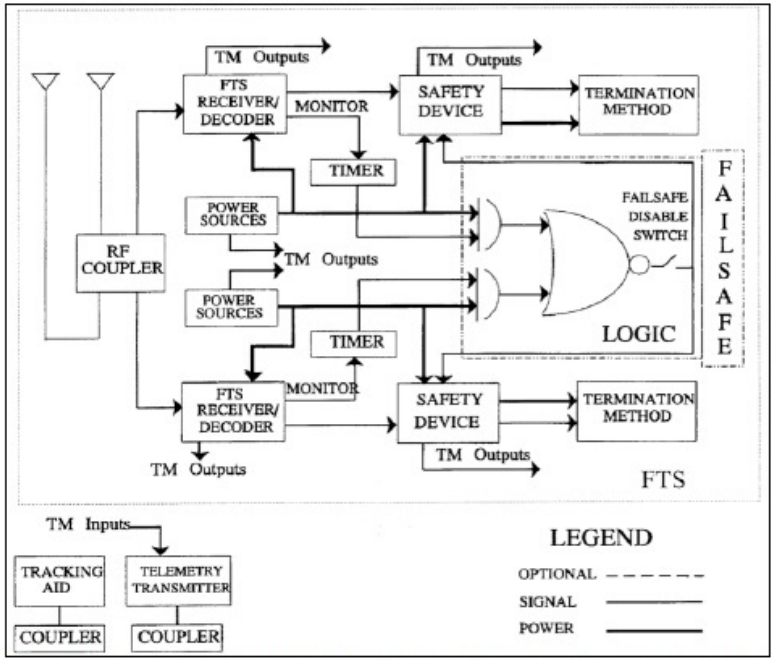


Figure 1-1. Typical Flight Safety System with Flight Termination System

RCC 319-14 Flight Termination Systems Commonality Standard

- **Previous analyses & reviews**
  - Assumptions on timing of core booster explosive impulse relative to side boosters drastically affects accident probabilities
- **System-specific SAR**
  - FTS custom-designed for Mars Exploration Rovers and New Horizons
  - Several different LVs and FTSs
- **Tier I, II, or III**
  - FTS can be designed to favor safety or launch execution

Conclusions

- NSPM-20 likely improves cost & schedule for radioisotope heater units (~32 curies ea.)-only missions like Mars Exploration Rovers and Mars Pathfinder
- NSPM-20 likely does not improve cost & schedule for MMRTG (~60,340 curies ea.) missions like EIM
- Need to consider all aspects of prior safety analysis reports, EISs, Nuclear Risk Assessments, reviews, test results, assumptions/ uncertainties/ unknowns
  - Need to look beyond their face value
- New safety technology can change prior risk results
- NSPM-20 may stagnate safety technology progress

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Thank you for attending!